A DAY AT AN ELECTRO-PLATE FACTORY.

[Silver-Deposit Room: Messrs. Elkington's, Birmingham.]

THERE are from time to time novelties introduced into manufactures, so startling, that it is difficult at first to regard them in the sober light of industrial processes; since they seem to belong rather to the marvellous than to the real. Who would have thought, for instance, of a silver vase or candelabrum, or any other article of table-plate, being made through the agency of electricity? It seems but a short time ago when all the phraseology relating to galvanic batteries, conducting fluids, positive and negative poles, chemical decomposition, &c. belonged exclusively to the lecture-room and scientific treatises; but now such terms form part and parcel of manufacturing processes, and electricity has become one of the working tools of productive industry.

Those who have paid a little attention to the recent progress of manufactures will perceive that we are alluding to the new art of *Electro-metallurgy*, or *Electro gilding* and *silvering;* but it is by no means generally known wherein the principle of this new art consists. To give such brief details as will convey this general knowledge is the object of the present paper; and, if we mistake not, the example which this process affords of the application of a scientific principle to practical purposes will be regarded as equally beautiful and interesting.

Without diving into the abstrusities of electrical science, it will be well to show how the idea arose of applying this agency to manufactures in metal. A galvanic battery is a vessel consisting of several cells or compartments containing a liquid, generally of an acid character, and into this liquid are immersed sheets of metal, generally copper and zinc. The precise arrangement adopted has undergone gradual changes, and is made dependent on the purpose in view, but the principle involved is very simple, and may be thus expressed:—Water consists of oxygen and hydrogen, and if a metal (such as zinc) which has a great affinity for oxygen is immersed in the water, there is a tendency to decomposition, the oxygen combining with the zinc to form oxide of zinc, and the hydrogen being liberated. But in order that this tendency may develop itself, it is necessary to place in the same liquid a piece of some other metal (such as copper) which has a less affinity for oxygen than zinc has, and to connect the copper with the zinc by a piece of wire. Other arrangements are necessary for getting rid of the oxide of zinc as fast as it is formed; but the point of importance is, that so long as the decomposition of the water and the oxidation of the zinc are going on, there is a current of electricity passing silently and invisibly through the whole arrangement in a continuous circuit.

Now it happened that in a particular form of battery devised by Professor Daniell, a solution of sulphate of copper was one of the liquids through which this electrical current passed in its progress; and the effect of the current was to decompose the sulphate, separate the copper from the sulphuric acid with which it was combined, and deposit it in a very fine metallic state upon the inner surface of the vessel which contained the liquid. It was afterwards observed, that on remov-

ing such a film of copper from the vessel, it presents an exact countertype of the surface of the vessel, every minute line or spot being faithfully copied. This was at the time regarded merely as a curious scientific fact; but it afterwards occurred to Mr. Spencer of Liverpool, Mr. Jordan of London, and Professor Jacobi of St. Petersburg (independently of one another), that copies of medals and of engravings might be made by these means; and thus arose an art which obtained the names of galvano-plastics, electrotype, and voltatype. The simultaneous progress of three persons towards the same result, in mutual ignorance of each other's proceedings, is something remarkable. Professor Jacobi's investigations became known in England about April, 1839; but Mr. Jordan, in the 'Mechanic's Magazine' for May of the same year, and Mr. Spencer, in the 'Athenæum' and other journals, a few months afterwards, showed that they had each been prosecuting such experiments before Jacobi's labours were made known.

By these steps, then, the broad fact became established that if a galvanic current passes through a liquid containing sulphate of copper, the copper will become precipitated on any surface fitted for its reception, and will present an exact counterpart of that surface. But the fact was not likely to remain long in that state: questions would arise whether other metallic solutions besides sulphate of copper could be employed, whether other metals than copper could be deposited, and whether other applications of the principle could be made besides simply copying engravings and medals. It was to these points especially that a patent taken out by Messrs. Elkington, about four years ago, was directed; and the result has been the establishment of a branch of manufacture as surprising perhaps as any thing exhibited at the present day. Not only copper, but silver and gold, as well as the cheaper metals, can now be precipitated in a metallic form from their solutions; and not only can a superficial film of these metals be deposited, but a solid article of pure gold, silver, or copper can actually be made by such means!

It would be taking us into too wide a field to trace the steps, and mention the persons, whereby various advances have been made in the theory or the practice of electro-working; but it will suffice, in conformity with the object of our "factory visits," to describe the present state of the art, as witnessed at a fine establishment belonging to Messrs Elkington, at Birmingham, to which we have been obligingly favoured with access.

This factory, situated in the northern part of Birmingham, comprises a large pile of buildings enclosing a square central court. On making the tour of the various ranges of rooms, it becomes presently evident that there is something more going on than the mere management of batteries and solutions; there is modelling and casting, stamping and punching, chasing and engraving, and a number of mechanical arts which have nothing either chemical or electrical in their general character. In point of fact there are almost as many mechanical processes carried on as if articles of plate were manufactured by the old method; for, although galvanic action deposits the costly metal in the required form, yet there must be a model or foundation presenting this form; and to prepare this foundation requires the aid of a whole range of ingenious mechanical processes. The nature of these operations and the arrangements of the different departments, may best be noticed as we go on.

Perhaps we may more clearly show the nature of the new process by comparing it with the old; and therefore we will endeavour to throw a hasty glance over most of the modes of producing articles which present a gold or silver exterior.

In all articles made of wood, plaster, or similar materials, the golden surface is produced by laying on thin sheets or leaves of gold, which are made to adhere by means of a glutinous gold size, and which are afterwards brought to a finished appearance by processes which are purely mechanical, and involve no chemical niceties. When, however, metals are to be coated with gold (or silver), a different range of processes is necessary, and many different means have been adopted. At one time polished iron, steel, and copper were gilt in France by the following means:—the metal was heated to a certain temperature, and on it was laid a leaf of gold of a particular thickness; this was burnished down, then heated, then another applied, then burnished and heated, and so on till several thicknesses were applied, after which it was burnished cold. 'Water-gilding' or 'wash-gilding' is a mode of applying a surface of gold to metallic articles by coating the article with a thin layer of gold amalgam (mercury and gold), dissipating the mercury by heat, and burnishing and otherwise finishing the golden surface which remains.

A mode of gilding was patented by Messrs. Elkington in 1836, which consists in the use of a solution of gold, in which the articles are immersed. The copper or other metallic articles to be gilt are, after being well cleansed, immersed in a boiling-hot liquid consisting of a solution of nitro-muriate of gold mixed with a solution of bi-carbonate of potash. This adhesion of the gold to the inferior metal takes place by a singular interchange, for a portion of the copper becomes dissolved by the action of the potash, and an equivalent of gold is deposited upon the copper article instead. We believe that this mode of gilding is now rather extensively adopted in France.

By slight modifications of the processes, silver may be applied in the same way as gold, as a superficial coating to other metals; and at various times, and in various countries, both the one and the other metal have been applied in the various states of amalgam, of leaf, of solution, of paste, and of powder.

A wholly distinct kind of work is that which is termed *plating*, in which a plate of silver is united to a plate of copper by mechanical means, the former being greatly thinner than the latter, and being intended for the outer surface of the article to be made. The French mode of silvering by laying leaves of silver on heated metal was so defective as to lead to the method of plating, which is, we believe, an English invention. An ingot of a mixed metal (copper and brass) is first made about twenty inches long, three broad, and one and a half thick. One surface of this ingot (or both if it is to be double plated) is cleaned, and on it is laid a sheet of silver about one-fortieth the thickness of the ingot; the two are tied together with wire, touched at the edges with a little borax to act as a flux, and exposed to the heat of a furnace, by which the two metals are soldered firmly together. This compound ingot is afterwards laminated in a rolling-mill to the form of thin sheets; and the sheets so formed are brought into ornamental forms by stamping, punching, hammering, and other mechanical processes, the copper foundation forming the substance of the article, and the silver side forming the exterior surface.

A great improvement on this manufacture was made at Sheffield some years ago by the introduction of what were called 'solid silver edges.' The ornamental edges of candlesticks and other articles, when merely stamped from thin plated metal, had the double disadvantage of being weak, and of having the silver surface soon rubbed away, leaving an unsightly copper surface exposed. The improvement consists in the following arrangement:—A sheet of silver is rolled to a state of great thinness; not so thin as leaf silver, but still

to a very attenuated state. This silver is stamped into form by means of dies, swages, and other apparatus; and the hollow cavity behind is then filled up with a soft whitish solder of lead and tin. These edges or ornaments are then soldered on any article of plated ware; and are at the same time stronger than the hollow edges before used, and less unsightly when the silver is partially worn off, presenting a whitish ground instead of one of copper. We shall shortly have to speak of a further improvement in the manufacture of these edges.

All the articles of manufacture yet alluded to are those which have only a superficial coating of gold or silver on a foundation of some cheaper metal. The real gold and silver plate, formed wholly of the noble metals, is, however, manufactured by mechanical means very similar to those employed in the plated manufacture. The articles are either cast in molten metal, or they are hammered and stamped from sheets, brought afterwards to a highly finished state by chasing, engraving, and burnishing.

These, then, are some of the principal modes in which gold and silver articles (or those presenting a gold or silver surface) were made before the introduction of the electric process, and still are made where this process is not employed. By following, now, the electro-metallurgic processes in their successive order, we shall see how far they are combined with any of the older processes, and how far they are wholly distinct from them.

The first department of the factory at Birmingham which we may notice is the artistic, where the taste of the artist devises those beautiful forms which are afterwards to be wrought in metal. Whether an article of plate to be manufactured be a candelabrum, a vase, a dish, or anything else, a considerable share of its beauty depends on its elegance of form and gracefulness of ornament; and the production of new designs becomes consequently a point of much importance. It has been pretty generally admitted, that in past times our neighbours the French have in most cases excelled us in the arts of ornamental design: but a rapid progress has been made in England of late years; and there is now a School of Design at Birmingham, partly supported by the government, whose object is to improve the taste of workmen in all that relates to forms, patterns, devices, and ornaments.

Next to the designer comes the modeller, who is also an artist in the proper meaning of the term; for he has to give in bold relief that which the designer presents merely on a flat piece of paper; and he ought to possess an extensive knowledge of the forms of objects, whether animals, plants, or lifeless things, in order to give truth and character to his models. The models to which we here allude are made of a flesh-coloured kind of wax, sufficiently firm to maintain its form uninjured, and at the same time very easily modelled and cut. The tools employed are principally pieces of bone, horn, or hard wood, brought at one or both ends to the forms of points, angles, curves, and edges of various kinds. With these small implements the modeller cuts and trims and works his lump of shapeless wax, till he brings it to the ornamental form which he may require.

When, by these preliminary operations, an exact copy or model in wax of the article has been prepared, the model is handed over to the workers in metal, by whom the pattern is transformed to a wholly different material. Here commences a new subdivision of labour, according to the mode in which the form of the metallic article is to be produced. Sometimes the form is given by casting, or pouring melted metal into moulds presenting a countertype to the article itself; sometimes by stamping, or imparting to sheets of metal an ornamental form by dies and stamps presenting this countertype: while in other cases the contour is given by brazing, or working up sheets of metal into various curved forms by means of the hammer. The decision as to which of these is employed in any particular case depends on a number of different circumstances, such as the thickness of the metal required, the general shape which it is to assume, and the amount of ornamental device on its surface. It not unfrequently happens that all three sets of processes are employed on one article, each to some one particular part; and indeed many of the excellencies of modern manufacture depend on this union of different modes of operation. We must describe these processes in succession, before an adequate idea can be formed of the complexity of the arrangements in the factory under notice.

The metal here spoken of, as the foundation for gilt and silver articles, is an alloy which has been chosen for many useful properties possessed by it. It is a mixture of copper, nickel, and zinc; hard in substance, infusible except at a high temperature, and white in colour. In past times, when a silver exterior covered a foundation of copper, the abrasion or wear of the silver laid bare the copper, and an unsightly appearance was the consequence; but it has been one of the objects in the modern improvement of the art to select some metal which, while possessing all other requisite qualities, should make a close approximation to silver in colour and appearance. The same proportion of ingredients is adopted: but in the case of castings, fragments and pieces of metal are thrown into the casting-pot to be melted; while in respect to stamped work, the ingots of mixed metal are sent to a rolling-mill, to be rolled to the form of sheets, varying in thickness according to the object in view.

There are many interchanges of form between the wax model and the white metal manufactured article. In the first place, from the wax model is made a mould in lead, by enclosing the model in a sort of frame or border (somewhat in the same way as for plaster of Paris castings), and pouring molten lead on it: this lead, when cold and removed from the model, constitutes an exact mould of the article, and the wax model has then performed its prescribed part in the routine of operations. From this lead mould a cast is taken in molten brass, by similar means; and it is easy to see that the brass cast is an exact copy of the original wax model. This cast is called technically the 'pattern,' and it is carefully examined to see that all the details of ornament are properly developed. Two or more pieces, separately cast up to this state, are often joined by a solder of copper and zinc; and a chaser goes over the whole pattern, to touch up the more delicate details with small cutting tools. When this pattern is once finished, the wax model and the lead mould are no longer wanted, the pattern becoming the source whence thousands of copies may be produced. As these brass patterns are both durable and rather costly, they are preserved so long as there is any probability of copies from them being required; and it thus results that a constantly accumulating stock of them is at hand. In the pattern-rooms of the factory the number and variety of these are altogether countless by a mere visitor; but they are, as may be expected, all orderly arranged and classed, so that the apparent chaos is no chaos to those immediately concerned.

We next transfer our attention to a room where workmen are engaged at troughs and trays containing sand. Here is another intermediate stage of operation. The brass pattern was itself made from a mould of lead; but it must also be the means of making a sand mould before the final white-metal article can be produced. Although the sand seems to be rather a rough

and common material, yet this operation is a very delicate one, and requires much tact and experience. The sand is of a peculiar kind, selected for the purpose, and is sifted and worked to a fine and smooth condition. When a sufficient body of sand is ready, the brass pattern is used to produce an indentation in the sand, so exactly effected that the cavity of the sand shall present in reverse every little detail of form and ornament on the exterior of the pattern; while a central core or plugging is at the same time applied so as to enable the metallic article to be made hollow, for the sake of lightness. It may well be imagined that the choice and preparation of the sand, to ensure a clear and smooth reverse of the brass pattern, must involve great nicety and care.

At length we come to the last stage in this singular train of transformations. The white metal, being brought to a melted state in pots or crucibles made of Stourbridge clay, is poured into these sand-moulds; and on being cooled and removed, the impression thus obtained is a copy of the wax model and the brass pattern, and then constitutes the body or foundation on which the deposit of gold or silver is afterwards to take place. The lead and the sand acted as moulds, but the wax, the brass, and the white metal were three different phases of the original design itself.

Here then we will leave for a time the white-metal cast, and proceed to visit a wholly distinct range of buildings in which the stamped work is under process of manufacture. If we regard the cast-work to be, from its nature, somewhat chemical, we shall find the stamp-work to be solely mechanical.

The ingots of white metal, measuring probably about a foot in length, by six inches in width, and an inch thick, are rolled into sheets, of which ten or twelve different thicknesses are required for different articles of manufacture. For some purposes, such as the pillars of candlesticks, the metal is required to assume the form of tubes; but for stamp-work the metal is always brought to the form of sheets. The stamping consists in imparting to a piece of flat metal, by repeated blows between two dies or stamps, the exact device which those two stamps present, forcing the metal into cavities, and raising it up at the convex parts of the pattern.

The preparation of these two stamps is evidently an operation preliminary to the stamping itself, bearing to it some such relation as the modelling does to the casting in the processes just described. A model in wax is prepared, representing the device to be produced, and this is transferred to the hands of the 'die-sinkers.' These persons take a block of steel or of iron, and by means of hammers and small hard steel tools cut a mould or die corresponding to the model, but of course reversed, having cavities instead of protuberances, and vice versâ. Two pieces are prepared for each pattern: one, the *die*—formed of steel for fine work, and of cast iron for coarse work—being intended to give the exterior surface of the stamped article; and the other, the *force*—formed of lead, of copper, or iron, according to circumstances—giving the hinder or hidden surface. The operation of die-sinking is slow and careful work, requiring considerable skill; and the dies thus prepared, when accumulated in considerable numbers, form a costly part of the working apparatus of the factory.

We have now to see how these dies are employed. In one of the lower departments of the factory are a number of large stamping-machines, by the aid of which the sheet of white metal is forcibly compressed between the die and the force of each pattern. A *pressure*, simply as such, will not produce the desired result; a *blow* is needed, and the arrangement of the machine is in conformity with this requirement. Each of the stamping-machines consists of a strong iron frame, having an iron mallet or hammer working vertically. This hammer is worked by a rope passing over a wheel above, and descending so as to be pulled by a workman. The 'force' is fixed, face downwards, to the lower surface of the descending hammer; while the die, face uppermost, is placed on a fixed solid block which receives the blows of the hammer. The sheet of metal, when cut to the required outline, is placed on the die; and the workman, by forcibly pulling the rope, raises the hammer to a considerable height; and letting it suddenly fall, the hammer descends with great power on the metal sheet, forcing it to assume the convexities and concavities which the two pressing surfaces present.

But the stamping involves more complications than are here mentioned. One blow will go but little way in forcing the metal into the desired form. Ten, twenty, or forty blows are often required; and to prevent the metal from being cracked or injured by these repeated percussions, it requires frequent annealing between the blows, to remove a temporary rigidity of surface which the force produces. It sometimes happens, too, where the pattern is very deep, that two or more pairs of dies are used, the first more shallow than the others, in order that the boldness of relief may be brought about more gradually.

A modified form of stamping is sometimes employed where small pieces of metal are to be punched or cut out of the sheet, instead of cavities and convexities being formed. This is effected by the aid of a small kind of press, having a lever-handle governed by the hand of the workman. Various kinds of ornamental pierce-work are produced by these means, the punches affixed to the press being selected according to the work to be done; and the lighter kind of stamping can also be done by similar means, when quickness rather than great force is required.

The third great variety in the mechanical formation of the article to be gilt or silvered, viz. the *brazing* or hammering, has yet to be noticed. If the white metal were of a rigid and unyielding character, it would neither bear the stamping nor the brazing; but it is chosen with reference to these points as well as others; and all such articles as dish-covers, and hollow vessels which are not cast in moulds, are brought up into form by the aid of the hammer. The hammers used for this purpose are made of some hard kind of wood, such as box, and covered with buff leather. There are also *bosses* or supports made of wood, on which the plate of metal is rested while being hammered. With these simple implements the process is conducted; a process calculated to excite some surprise in the mind of a looker on; for the flat sheet of metal gradually loses its original form and assumes curvatures which one would scarcely expect that the metal would bear. But this, like every other mechanical operation, requires that nicety and tact which long practice alone can give. The brazier, by minute changes in the mode of holding the sheet of metal, and in the direction and weight of the blow, forces, or perhaps we may say *entices*, the metal to assume the desired curvature of form. Sometimes a vessel, instead of being brought at once from a flat sheet, is first soldered up into the form of a cylinder or a cone; and this cylinder or cone is transformed into a vase or some other vessel by means of the hammer.

There is a collateral aid, of which the brazier avails himself, to impart something like pattern to parts of his work: this is by the use of *swages*. A swage is a double instrument, analogous (for the sake of familiar illustration) to a pair of scissors, having some kind of device on each of its halves, the one a counterpart of the other. A thin piece of metal being drawn between these two closed halves, is forced to assume a form cor-

responding to them; and thus mouldings, beadings, and raised edges are given to sheets of metal which are in other respects worked into form by the hammer.

[Swaging.]

Let us now gather up the scattered details which have hitherto occupied our attention, and see to what point they lead us. The grand object in view is to bring a mixed white metal into some one or other of the countless ornamental forms which the shop of the gold and silver smith presents to us; and this is effected by casting, by stamping, by pressing, by punching, by hammering, and by swaging, according to the circumstances of each particular case. It thus arises, that the mechanical department of the factory is very extensive, irrespective of the chemical and galvanic arrangements yet to be noticed. The quadrangular ranges of buildings exhibit tier after tier of shops, in which many hundreds of men are thus engaged; each class totally distinct from the others, and carrying on in fact a different branch of manufacture. One department, for instance, comprises the spoon and fork manufacture; in which by means of dies, presses, and stamps the pieces of white metal are brought to the well-known forms of those implements, preparatory to the surface processes.

It often happens, and generally does happen in a large and complicated piece of ornamental plate, that its manufacture from one piece of metal is utterly impracticable; it consists of numerous component pieces, some of which may be more fittingly prepared by casting than by any other of the mechanical processes, others by stamping, others by hammering, and so on; and an important object then is to solder all these pieces together into one complex whole. This brings us to another remarkable department of the factory; one which exemplifies the recent striking advance made in this kind of work. So long as plated-ware was made on the old method, soft or fusible solder alone could be used; because hard solder, which melts only at a high temperature, would endanger the melting of the metal itself which is to be soldered. But the white metal now employed is so hard, and capable of bearing so high a temperature, that solder of a very different kind can be used; a solder, indeed, so refractory that the common process is inapplicable to it. Hence a powerful heat is required, and this heat is obtained by a method patented by M. Delbruck a few years ago, and known as "autogenous soldering," the use of which in England is obtained by licence from the patentee. The method consists in the application of a forcible jet of mixed gases, in an ignited state, to the metal. In one of the ranges of shops are several iron stands or tables ranged in a row, each one contiguous to a jet affixed to a flexible pipe. The gases are forced along this pipe with great violence, by steam power, from another part of the building; and the stream, when issuing from the pipe and ignited, gives out a most intense heat. The articles to be soldered are adjusted to each other, with a little of the hard solder between them, and a little borax to act as a flux; and the pipe is held in the hand of the workman so as

[Soldering.]

to direct the intensely heated jet down upon the metal. The apparatus is so perfectly manageable, that the heat can be directed to any particular point; and the solder becoming melted, the two pieces of metal become joined together with a firmness which never could be attained under the older process. The hollow parts of some of the ornaments are filled up with hard metal by similar means, thereby forming a much more solid foundation than the lead and tin used in earlier times.

As the surface of the white metal, by these complicated processes of casting, stamping, hammering, soldering, &c., has become rather soiled and discoloured, it undergoes a thorough cleaning, grinding, and polish-

ing, which is effected by means of emery, sand, or rottenstone, applied either by means of a grinding-wheel or of brushes, according to the nature of the work.

At length we approach the electro-chemical departments of the factory, those which form the most striking feature of the whole. It is not from their size, for the rooms are but small; it is not from the complex arrangement, for nothing can be more simple and plain than their general appearance; it is not from the number of persons employed, for two or three individuals can coat with gold or silver all the articles which many scores of men have been employed to make. It is not from any of these causes, but from the beautiful exemplification which these rooms exhibit of the application of a scientific principle to productive industry, that we feel this to be the heart and centre of the whole factory. There is the copper-deposit room, the silver-deposit room, and the gold-deposit room, all of which will call in turn for notice.

We have in an earlier paragraph explained, that if a galvanic current passes through a vessel containing a metallic solution, the metal becomes separated from the liquid, and deposited in a solid form. But it is not every surface which is fitted for the reception of this deposit. In the earlier stages of this new art, when it was regarded simply as a curiosity, the metal deposited was always copper, and the surface on which the deposition took place was also metallic. When, however, it was proposed to take electro-types or copies from articles in wax, plaster, or other materials, a necessity arose for some means of imparting to these substances the power of receiving the deposit; and black-lead applied in powder was found to be tolerably well fitted for this object. In the further progress of the art towards the state of a manufacture for commercial purposes, a more complete and efficacious agent was sought, in lieu of black-lead, where the substance on which the deposit takes place is not metallic. The use of a preparation of phosphorus for this purpose, patented, we believe, by Messrs. Elkington, has been the means of coating with gold and silver various beautiful organized substances, of which we shall speak presently.

The silver-deposit room, of which a general sketch is given in the frontispiece, contains a range of tanks or troughs, about a yard in width and the same in height, and three or four yards in length. Wires and rods are placed across and within these tanks, so arranged as to bring the contents of the tanks in connexion with a galvanic battery contained in an adjoining apartment. This battery consists of thirty or forty upright cylinders, about two feet high, with such an arrangement of copper, zinc, and an intervening liquid, as to give rise to a powerful and continuous galvanic current. Two wires, the positive and the negative, extend from this apparatus to the tanks in the deposit-room, so that the contents of the tanks may form part of the galvanic circuit; or, in other words, a current of galvanic electricity is made to pass through the tanks.

In these tanks is contained a solution of a double salt, the cyanide of potassium and silver. This choice of solution is the result of a vast number of experiments, instituted with the view to determine what kind of solution will most fittingly and readily yield metallic silver when exposed to electric action; the selection being guided by numerous little points which can only be appreciated by those immediately engaged in the manufacture. Into these tanks, thus supplied with a silver solution, the white-metal articles are immersed; but before being so they are brought to a perfectly bright and clear surface by being boiled in caustic potash, and afterwards dipped in a solution of aqua-fortis.

The mode of immersing the articles is curious: metallic rods cross the tanks from side to side, and from these the various articles are suspended by wires temporarily affixed to them. Spoons, forks, plates, salvers, cups, candlesticks, candelabra, and a countless assemblage of other articles, are thus suspended side by side, but without being in contact; the general arrangement of the tank, as to the pointing of the wires, &c., being regulated according to the kind of articles to be coated. The galvanic current, conducted through the tanks thus occupied, and brought into connexion with all the various parts by a sufficiency of conducting wires and rods, decomposes the solution, liberates the silver from the other component elements, and deposits it in a beautifully clear and equable layer on the articles hanging in the tank. By increasing or decreasing these four agents—the intensity of the galvanic current, the quantity of the current, the strength of the solution, and the time of immersion—any desired thickness of silver may be deposited; the determination of all these points being a matter of experience on the part of those employed. As, from the peculiar nature of the process, the quantity of silver deposited cannot be ascertained while the deposition is going on, it is determined by weighing the article accurately before immersing it in the solution, and after it is finished; the former weight subtracted from the latter, gives the weight of silver deposited. If the solution be acted on for a long time together, it would become exhausted of its silver, and the process would stop for want of working materials; to obviate which, sheets of pure silver are suspended in the tanks at intervals, and the silver from these sheets becomes dissolved as fast as deposition takes place; so that the solution is constantly receiving on the one hand an equivalent for what it is giving up on the other. These sheets of silver are gradually eaten away till they present nothing but a delicate web of lace-like fibres, extremely beautiful in appearance.

The gold-deposit room, of smaller dimensions, presents to view operations nearly analogous to those here noticed. The quantity of work being generally smaller in gold than in silver, a smaller working agency is required; and the galvanic battery is here placed by the side of the depositing tank. The solution is analogous in composition to that for the silver; being a double salt, the cyanide of potassium and gold. In the silver deposit, the solution is used quite cold; but in the gold deposit it is used at a temperature of more than a hundred degrees, a ring of gas-jets being so arranged beneath the tank as to heat the solution to the required temperature. Near the tank are other vessels containing aquafortis and other liquids, into which the articles are dipped before being immersed in the deposit-tank. If small articles of jewellery, or anything that can be strung upon a wire, are to be gilt (and this is becoming an extensive department of the operations), a wire-ful of such is dipped in the solution while the galvanic action is going on; and by a little agitation, all the articles are coated with pure gold in a space of time hardly credible to those who witness it for the first time. We saw ten gross of coat-buttons strung upon a wire and all perfectly gilt by an immersion of less than one minute! A strip of pure gold is bent round the interior of the tank, as a source of supply to renovate the exhausted solution.

Remarkable as these processes are, yet perhaps the most strikingly curious are those in which any small delicate natural productions are coated with silver or gold. In the show-rooms of the factory are many little slips of holly and other plants, coated some with pure gold, some with silver, and others with copper; all exhibiting the minute details of leaf and fibre with exquisite clearness, and every part, to the mere prickles on the edges of a leaf, being coated evenly and equally

with pure metal. So complete is the method by which this is now done, that a stranger may see a small slip from a shrub dipped in a solution of phosphorus, and immediately afterwards in the deposit-tank, where it is instantly coated with the metal. There are also specimens of butterflies and other insects, coated with gold or silver in the same manner, and exhibiting much of the delicate mechanism of the surface. It is impossible adequately to foretel the vast number of useful applications which may one day result from this extremely facile mode of imparting a coating of absolutely pure metal to almost any substance whatever.

But to return to the electro-plate. Many highly finished articles present a silver exterior with a gilt interior. This is effected by the electro process thus: the article is first silvered in the way just described; and the surface is then coated with some protective composition which will resist the deposition of gold. The article is next transferred to the gold-deposit room, where a film of gold is deposited on the side or surface required, without attacking the opposite side. This principle is carried still further, in some kinds of ornamental plate, by interspersing gold among the silver in very tasteful array; the silver, in every such case, being protected from the subsequent action of the gold at every place where the latter metal is not required to be deposited.

The reader will have observed, that in all the details through which we have passed, the operations have had relation to a substance or body of white metal coated with a layer of pure gold or silver. But before we trace these gilt and silvered articles through the finishing processes yet to be noticed, it is necessary to go back a little, and glance at the manufacturing history of a class of articles which are perhaps the highest triumph of electro-metallurgy; viz. those in which not only the surface, but the actual substance of the article is wholly formed by electro-deposition. To manufacture a silver vase or salver from a liquid solution, seems a strange thing to undertake; yet it is scarcely an exaggeration of things actually done, as the following details will show.

The interchange between mould and model, mould and model again, is greater for this department than for mere surface deposit. Supposing an elaborate design to be wrought in wax by the modeller of the intended article of plate, this wax model is moulded in lead, from which again a brass pattern is cast, and this pattern is brought up to the required degree of finish. From this model or pattern a second mould is made; not in sand as for surface deposit, but in a very peculiar elastic composition, formed of glue, caoutchouc, and other materials. The pattern is enclosed in a frame or border, and the melted composition is poured upon it. When cold this composition is removed from the pattern in one piece, its elastic nature being such that it may be loosened and removed from under-cut and deep hollows in the device, such as would be quite unmanageable in a rigid material. Then from this mould a model or pattern is cast in a composition of wax, suet, and phosphorus, and the model thus produced forms a surface on which electro-deposition is to take place. The elastic mould is removed with facility from the model, by reason of its peculiar yielding quality. The composition model is next transferred to the copper-deposit room, where a large tank, vessels with the preparing liquid, and an adjacent battery, furnish the means for bringing about the deposition of copper on the surface of the wax model. In the tank is a solution of sulphate of copper, and in an adjoining vessel is another solution of nitrate of silver. The choice of ingredients altogether has been the result of an elaborate series of inquiries, and is such that the phosphorus contained in the composition, induces the deposition of a thin layer of silver from the nitrate solution. This being effected, a preparation is afforded for the subsequent deposit; and the model is then immersed in the solution of sulphate of copper. The galvanic current, acting in the manner before described, decomposes the metallic solution, and precipitates the liberated copper on the surface of the model (or rather, on the slight silver layer already covering it), coating it with a layer of metallic copper more or less thick according to the circumstances under which the operation is conducted.

Here, then, we have a wax or composition model coated on the exterior with an equable layer of fine pure copper. At the factory we saw a large dish of most elaborate workmanship in the tank, and in the act of being coated with a glowing and richly-coloured film of copper; the dish was made of the wax composition, and had been brought to that form by the processes already enumerated; it was in an intermediate stage between the preparatory and final depositing processes, and exhibited the real colour of copper in a more uncontaminated state, perhaps, than any other department of manufacture exhibits it.

As the wax is only a mere foundation for the copper, so is the copper only a step towards the ultimate gold or silver article, and both have to be destroyed in succession. In the first place, when the copper deposition is properly completed, the wax composition is melted out, leaving a mere copper shell, the *interior* of which is an exact mould of the *exterior* of the wax model. This copper mould, after a further preparation, is immersed in the gold or the silver solution, the interior being prepared for the reception of the deposited metal, but the exterior protected from it by a resisting composition. Then, by the agency before described, the silver is deposited in the copper shell or mould, to any thickness that may be required, the particles of metal ranging themselves equally over every part of the interior. This being completed, the specimen is removed, and the copper is exposed to the action of an acid which gradually eats it away without injuring the silver; and the result is the production of a pure and solid silver ornament or article of table plate, having not a single particle in or about it but what has been deposited from the liquid solution in the tank.

It thus appears that the changes of form by which the article is ultimately produced, are, in many such cases, singularly numerous: four such changes are shown in the next cut, where *a* is the model; *b*, half

of the elastic mould; *c*, the deposited copper when taken therefrom; and *d*, the finished vessel of silver.

Here we leave the electro-deposit rooms, and turn our attention briefly to the departments of the factory where the finishing processes are being carried on. The silver and gold articles, whether of solid deposit or superficial deposit, have a singularly dead appearance when removed from the solution; the silver, in particular, presenting a hue which, to a stranger, does not appear to bear much analogy to that of silver. To give a somewhat more metallic appearance to the surface is the object of one of the first operations after the deposition.

The silver is well rubbed with 'scratch-brushes' made of brass wire; and is then burnished. To give this burnish is the work of a large number of females, who work in a part of the factory appropriated wholly to them, and who earn a respectable living by this employment. The burnishing is effected chiefly by

[Burnishing.]

pieces of blood-stone, a very peculiar kind of Derbyshire stone, which, from its hardness and smoothness, is highly valuable in burnishing gold and silver work. The burnisher, which is fixed in a handle, and is held in such a manner as to give considerable power of pressure on the work, is first moistened to prevent it becoming too hot, and is rubbed rather forcibly over every part of the article which is to be burnished, by which a surface of exquisite brilliancy is produced.

There is a process to which large metallic surfaces are subjected, after the deposition, which exemplifies the close and intimate union which has taken place between the deposited metal and the foundation metal beneath it; this is *planishing* or *hammering*.

The hammering seems to have the effect of bringing the metallic particles into more intimate

[Planishing.]

union than they were before, and to give an elastic and homogeneous texture, highly conducive to the durability of the article. The pieces of plate are placed on a supporting boss or block, and are hammered with a highly polished steel hammer in every part. Not only is this done with flat articles which have been electro-plated on white metal, but also on articles of solid deposit themselves; and the fine sonorous 'ring' which these emit when struck, shows that the atoms of silver and gold, although thrown down from a liquid solution, have assumed the aggregate form of a sound continuous sheet of metal—a circumstance not among the least curious which the range of processes exhibits.

Another class of finishing operations is that which relates to the engraving, and which occupies the attention of a different set of workmen from those yet noticed. Many of the finer articles of plate have ornamental devices put upon them by the engraver, who works with tools somewhat similar to those employed by other engravers. Sometimes, where the engraving is made on an article plated with silver or gold on a cheaper metal, the costly metal is either deposited more thickly than usual on the part to be engraved, to give scope for the incisions of the graver without reaching the inferior metal beneath, or an extra deposit is precipitated on the engraved part after the engraving is completed.

Here we close our rapid sketch of a factory which exhibits a greater number of distinct and often widely different processes than almost any which we have had to notice in the 'Magazine.' There may be some in which the artistic features are carried to a greater height, some more mechanical, some more chemical; but for a combination of all these three—taste, mechanical operations, and chemistry, or rather electro-chemistry—there are probably scarcely any to equal it. Many of the processes, too, are altogether out of the common run of things, and our thanks are all the more due for the liberality which granted us access and facilities for observing the operations.